Indian Journal of Health Care, Medical & Pharmacy Practice (Vol 7, Issue 2, July-December 2026)
Home page of the journal: https://ijhmp.com/Home

Research Article

METABOLIC ACIDOSIS IN CRITICALLY ILL PATIENTS IN THE INTENSIVE CARE UNIT: CLINICAL PROFILE AND TREATMENT OUTCOMES

Dr. Prajapati Raj Vishnubhai[1], Dr Bindu Rani[2]*

[1]Postgraduate Resident, [2]Professor, Department of General Medicine, National Institute of Medical Sciences & Research, NIMS University Rajasthan, Jaipur, India.

Corresponding Author*: Dr Bindu Rani, Professor, Department of General Medicine National Institute of Medical Science and Research, Nims University Rajasthan, Jaipur, India.

Email ID: bindurani2004@rediffmail.com

DOI: https://doi.org/10.59551/IJHMP/25832069/2026.7.2.163

How to cite this article: Vishnubhai PR, Rani B. Metabolic Acidosis in Critically ILL Patients in the Intensive Care Unit: Clinical Profile and Treatment Outcomes. *Indian J. Health Care, Med. Pharm. Pract.* 2026;7(2):414-418.

Received: 27 July, 2026, Decision for Acceptance: 10 Sept, 2026

ABSTRACT

Background: Metabolic acidosis is a frequent acid–base abnormality in critically ill patients and may reflect sepsis, shock, diabetic ketoacidosis, renal dysfunction, or other severe systemic disorders. Its severity and persistence may influence the need for organ support and ICU outcomes.

Aim: To assess the clinical profile of metabolic acidosis in critically ill patients admitted to the intensive care unit and to evaluate its association with treatment outcomes.

Methods: A prospective observational study was conducted in the Medical Intensive Care Unit of the National Institute of Medical Sciences & Research Hospital, Jaipur, from July 2024 to December 2025. Adults (>18 years) with metabolic acidosis identified within the first 24 hours of ICU admission were enrolled. Metabolic acidosis was assessed using arterial blood gas parameters, bicarbonate, anion gap and lactate. Disease severity, organ-support requirements, treatment modalities and ICU outcomes were recorded. Statistical analysis was performed using SPSS and Microsoft Excel.

Results: Seventy-seven patients were included. Mean age was 47.48 ± 16.90 years (range, 19–84 years), and 42 (54.5%) were male. Sepsis was the most frequent underlying diagnosis (18/77, 23.4%), followed by diabetic ketoacidosis (12/77, 15.6%), chronic kidney disease (10/77, 13.0%) and acute kidney injury (9/77, 11.7%). High anion gap metabolic acidosis predominated (49/77, 63.6%). Mean pH was 7.23 ± 0.07, bicarbonate 13.16 ± 3.18 mmol/L, $PaCO_2$ 30.8 ± 5.9 mmHg, base excess −10.5 ± 4.1 mmol/L, lactate 5.19 ± 1.87 mmol/L and anion gap 18.10 ± 5.07 mmol/L. Mean APACHE II score was 20.70 ± 9.09 and mean ICU stay was 8.83 ± 3.14 days. Mechanical ventilation was required in 32 (41.6%), inotropic support in 42 (54.5%) and renal replacement therapy in 34 (44.2%) patients. Overall, 43 (55.8%) recovered and 34 (44.2%) expired. Ventilatory support was significantly associated with outcome ($p = 0.017$), whereas inotropic support ($p = 0.962$) and renal replacement therapy ($p = 0.284$) were not.

Conclusion: In this single-center cohort, metabolic acidosis was associated with substantial ICU mortality and a high burden of organ-support requirements. High anion gap acidosis was predominant, with sepsis being the most common underlying diagnosis. Early recognition, serial acid–base assessment and prompt treatment of the underlying cause remain central to ICU management. Larger multicenter studies are needed to determine independent prognostic factors and the impact of specific treatment strategies.

KEYWORDS: Metabolic Acidosis, Intensive Care Unit, Arterial Blood Gas, Anion Gap, Lactate, APACHE II, Mechanical Ventilation, ICU Mortality.

Introduction

Metabolic acidosis is a common acid–base disturbance in critically ill patients and generally reflects a reduction in systemic bicarbonate with associated acidemia. In the ICU, it is rarely an isolated biochemical abnormality; rather, it commonly accompanies severe systemic disorders such as sepsis, shock, renal failure, diabetic ketoacidosis and multiorgan dysfunction. Reduced tissue perfusion may increase lactate production, while impaired renal acid excretion may further aggravate the disturbance[1-4].

The clinical consequences of significant acidemia include impaired myocardial contractility, reduced vascular responsiveness to catecholamines, altered cellular metabolism and electrolyte disturbances. Severe or persistent acidemia may therefore coexist with hemodynamic instability and progressive organ dysfunction. Lactate, base deficit, pH and anion gap have been studied as markers of severity and prognosis in critically ill populations[5-7].

Classification by anion gap helps distinguish accumulation of unmeasured anions from bicarbonate-loss states. High anion gap metabolic acidosis may occur with lactic acidosis, ketoacidosis, renal failure and selected toxic exposures, whereas normal anion gap acidosis is more commonly associated with gastrointestinal or renal bicarbonate loss and hyperchloremia[8-9].

Although correction of the underlying cause is fundamental, management frequently requires simultaneous supportive interventions such as fluid resuscitation, vasopressors, mechanical ventilation and renal replacement therapy. The role of bicarbonate therapy remains context dependent, and correction of the biochemical abnormality alone does not necessarily translate into improved survival[4,6,10].

The present study was undertaken to characterize metabolic acidosis among critically ill adults admitted to a tertiary-care ICU and to examine its relationship with treatment requirements and immediate ICU outcome.

Materials and Methods

Study Design and Setting

This was a prospective observational study conducted in the Medical Intensive Care Unit of the National Institute of Medical Sciences & Research Hospital, Jaipur, Rajasthan. The study period was 1 July 2024 to 31 December 2025 (18 months).

Participants

Adult patients aged >18 years with metabolic acidosis within the first 24 hours of ICU admission were eligible. Metabolic acidosis was defined in the study protocol by arterial pH <7.35, bicarbonate <22 mEq/L and assessment of the anion gap. Patients with mixed or primary respiratory acidosis, patients younger than 18 years and those declining participation were excluded.

Sample Size and Sampling

The calculated sample size was 77 participants, based on a 95% confidence level, an assumed standard deviation of APACHE II score of 1.35 and a precision of 0.30 as stated in the study protocol. Purposive sampling was used.

Data Collection

After institutional scientific and ethics approval, written informed consent was obtained from patients or legally authorized representatives. Demographic and clinical information, primary diagnosis, comorbidities, arterial blood gas parameters, lactate, anion gap, APACHE II/SOFA assessment, treatment modalities, organ-support requirements and ICU outcomes were recorded using a structured case record form.

Outcome Measures and Analysis

The principal outcome was ICU treatment outcome, categorized as recovered or expired. Secondary measures included ICU length of stay and requirements for mechanical ventilation, inotropic support and renal replacement therapy. Data were analyzed using SPSS and Microsoft Excel. The study reports descriptive statistics and categorical associations with $p < 0.05$ considered statistically significant.

Results

A total of 77 adult patients with metabolic acidosis were included. The mean age was 47.48 ± 16.90 years, with a range of 19–84 years and median age of 42 years. Patients older than 60 years constituted the largest age category (23.4%). There was a slight male predominance, with 42 (54.5%) males and 35 (45.5%) females (Table 1).

Sepsis was the most frequent underlying diagnosis, followed by diabetic ketoacidosis, chronic kidney disease and acute kidney injury. High anion gap metabolic acidosis was observed in 49 patients (63.6%), while 28 (36.4%) had normal anion gap metabolic acidosis.

The mean pH of 7.23 ± 0.07 and bicarbonate of 13.16 ± 3.18 mmol/L confirmed clinically relevant acidemia and metabolic bicarbonate depletion. The mean $PaCO_2$ of 30.8 ± 5.9 mmHg was consistent with respiratory compensation. Mean lactate was 5.19 ± 1.87 mmol/L and mean anion gap was 18.10 ± 5.07 mmol/L. The mean APACHE II score was 20.70 ± 9.09, reflecting substantial physiological illness severity, and the mean ICU stay was 8.83 ± 3.14 days (Table 2).

Mechanical ventilation was required in 32 (41.6%) patients, inotropic support in 42 (54.5%) and renal replacement therapy in 34 (44.2%). Antibiotics were the most frequently documented treatment modality (18.2%), followed by insulin, vasopressors, and combined fluids with vasopressors (14.3% each) (Table 3).

Overall, 43 (55.8%) patients recovered and 34 (44.2%) expired during ICU admission. Among patients receiving ventilatory support, 23/32 (71.9%) recovered compared with 20/45 (44.4%) among those not receiving ventilation; the association was statistically significant ($p = 0.017$). Inotropic support was not significantly associated with outcome ($p = 0.962$), nor was renal replacement therapy ($p = 0.284$).

ISSN 2583-2069

Table 1: Demographic characteristics and underlying diagnoses of study participants (n = 77)

Characteristic	n	%
Mean age, years	47.48 ± 16.90	—
Age range, years	19–84	—
Male sex	42	54.5
Female sex	35	45.5
Age >60 years	18	23.4
Sepsis	18	23.4
Diabetic ketoacidosis	12	15.6
Chronic kidney disease	10	13.0
Acute kidney injury	9	11.7
Poisoning	8	10.4
Liver disease	7	9.1
Shock	7	9.1
Other diagnoses	6	7.8

Table 2: Acid–base and severity parameters

Parameter	Mean ± SD
pH	7.23 ± 0.07
HCO_3^-, mmol/L	13.16 ± 3.18
$PaCO_2$, mmHg	30.8 ± 5.9
Base excess, mmol/L	−10.5 ± 4.1
Lactate, mmol/L	5.19 ± 1.87
Anion gap, mmol/L	18.10 ± 5.07
APACHE II score	20.70 ± 9.09
ICU stay, days	8.83 ± 3.14

Table 3: Organ-support requirements and treatment modalities

Variable	n	%
Mechanical/ventilatory support	32	41.6
Inotropic support	42	54.5
Renal replacement therapy	34	44.2
Antibiotics	14	18.2
Insulin	11	14.3
Vasopressors	11	14.3
Fluids + vasopressors	11	14.3
Fluids	10	13.0
Dialysis	8	10.4
Bicarbonate	7	9.1
Bicarbonate + dialysis	5	6.5

Table 4: ICU outcome and association with organ-support interventions

Intervention	Recovered	Expired	Total	Recovery %	p-value
Ventilatory support: Yes	23	9	32	71.9	0.017
Ventilatory support: No	20	25	45	44.4	
Inotropes: Yes	25	17	42	59.5	0.962
Inotropes: No	18	17	35	51.4	
RRT: Yes	17	17	34	50.0	0.284
RRT: No	26	17	43	60.5	

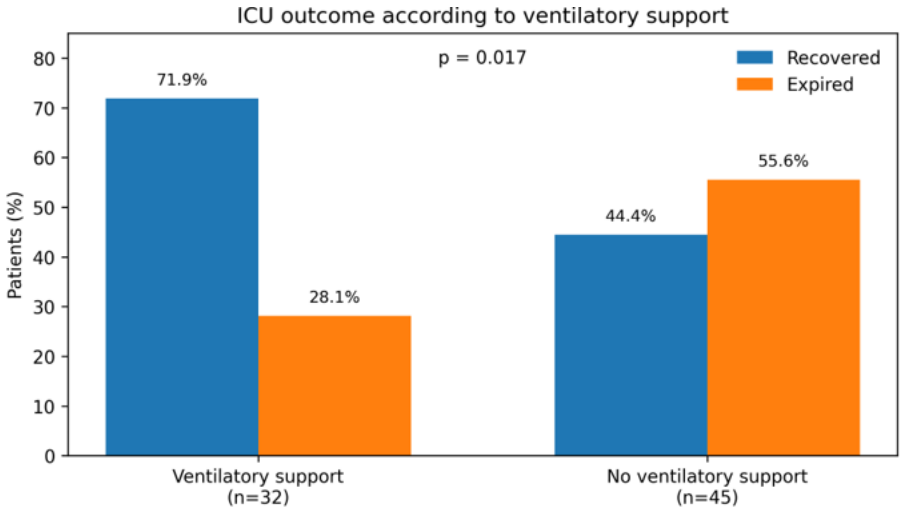

Figure 1.ICU outcome according to ventilatory support. The study reported a statistically significant association between ventilatory support and outcome (p = 0.017)

Discussion

The present study demonstrates that metabolic acidosis in critically ill adults is associated with a substantial burden of illness, organ-support requirements and ICU mortality. The study population had a mean age of 47.48 years, with a slight male predominance. Sepsis was the leading underlying diagnosis, followed by diabetic ketoacidosis and renal disorders. This pattern is clinically plausible because critical illness frequently combines impaired perfusion, increased acid production and reduced renal acid excretion[1-4].

High anion gap metabolic acidosis was the predominant pattern, occurring in 63.6% of patients. The mean anion gap of 18.10 mmol/L and lactate of 5.19 mmol/L support the importance of unmeasured anions and tissue hypoperfusion in this cohort. The predominance of high anion gap acidosis is consistent with the recognized contribution of lactic acidosis, ketoacidosis and renal dysfunction in critically ill patients[8-11].

The mean pH of 7.23 and bicarbonate of 13.16 mmol/L indicate a clinically meaningful metabolic disturbance. The accompanying lower $PaCO_2$ suggests compensatory hyperventilation. Severe acidemia can impair cardiovascular performance and catecholamine responsiveness, while persistent acidemia may signal unresolved hypoperfusion, infection or organ dysfunction[2,5,7].

The mean APACHE II score of 20.70 and mean ICU stay of 8.83 days indicate a substantially ill cohort requiring prolonged intensive care. Previous work has linked severe metabolic acidosis, base deficit and lactate abnormalities with higher mortality and more complex ICU courses[2,5,7]. The present findings therefore reinforce the role of acid–base assessment as part of broader severity evaluation rather than as an isolated prognostic variable.

A notable finding was the statistically significant association between ventilatory support and outcome. Recovery occurred in 71.9% of patients receiving ventilation compared with 44.4% of those who did not. This should not be interpreted as evidence that ventilation itself improves survival. The association may reflect differences in underlying disease, timing of intervention, clinical selection and other unmeasured confounders. In contrast, inotropic support and renal replacement therapy were not statistically associated with outcome in this sample. These interventions are typically initiated according to clinical severity and organ dysfunction, so lack of a statistical association should not be interpreted as lack of clinical importance.

Antibiotics were the most frequently documented treatment modality, consistent with sepsis being the leading diagnosis. Other treatments included insulin for metabolic indications, fluids and vasopressors for hemodynamic support, dialysis/RRT for renal dysfunction or refractory metabolic disturbance, and

ISSN 2583-2069

bicarbonate in selected patients. Contemporary management emphasizes treatment of the underlying cause, with bicarbonate therapy reserved for selected clinical situations because improvement in biochemical parameters does not consistently translate into lower mortality[4,6,10].

Overall ICU mortality was 44.2%. This high mortality should be interpreted in the context of a selected population already identified as critically ill with metabolic acidosis, rather than as a mortality estimate for all ICU patients. The findings support early recognition, serial ABG and lactate assessment, anion-gap evaluation, and rapid identification and treatment of the underlying disease process.

Strengths and Limitations

Strengths: The study prospectively evaluated adult ICU patients, incorporated clinical assessment with ABG, lactate and anion-gap measurements, and captured treatment modalities, organ-support requirements and ICU outcome within a defined tertiary-care setting.

Limitations: The study was conducted at a single center and included a relatively small sample selected by purposive sampling. The short outcome window limits assessment of longer-term mortality and functional recovery. Multiple comorbidities and differences in disease severity may have confounded associations between interventions and outcomes. The study did not compare conventional anion-gap assessment with advanced physicochemical approaches such as the Stewart method or strong-ion difference analysis. These limitations restrict generalizability and preclude causal interpretation of the observed associations.

Conclusion

Metabolic acidosis in critically ill adults was characterized by frequent high anion gap acidosis, elevated lactate, substantial physiological derangement and a high requirement for organ support. Sepsis was the most common underlying diagnosis. Nearly half of the cohort died during ICU admission, and ventilatory support showed a statistically significant association with outcome, whereas inotropic support and renal replacement therapy did not. Early recognition, serial monitoring and prompt treatment of the underlying etiology remain essential components of care. Larger multicenter prospective studies with standardized severity adjustment are warranted to identify independent predictors of outcome and clarify the impact of individual treatment strategies.

Ethical Considerations

The study was conducted after permission from the Institutional Scientific and Ethics Committee of the National Institute of Medical Sciences & Research, Jaipur. Written informed consent was obtained from participants or legally authorized representatives, as described in the study protocol.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Jung B, et al. Severe metabolic or mixed acidemia on intensive care unit admission: incidence, prognosis, and administration of buffer therapy. Crit Care. 2011;15(1):R1.
2. Gunnerson KJ, Kellum JA. A retrospective outcome evaluation of critically ill patients. Crit Care Med. 2006;34(1):122–128.
3. Achanti A, et al. Acid-base disorders in the critically ill patient. 2022.
4. Yagi K, et al. Management of acute metabolic acidosis in the ICU. Crit Care. 2021;25(1):1–10.
5. Henrique LR, et al. Prognosis of critically ill patients with extreme acidosis. J Crit Care. 2023;68:10–15.
6. Lo KB, et al. Bicarbonate use and mortality outcome among critically ill patients with high anion gap metabolic acidosis. Clin Nutr. 2020;39(4):1222–1230.
7. Jamme M, et al. Severe metabolic acidosis after out-of-hospital cardiac arrest. Ann Intensive Care. 2018;8:113.
8. Park MAJ, Cave G, Gregory K. Metabolic acidosis in anaesthesia and critical care. BJA Educ. 2024;24(3):91–99.
9. Kraut JA, Madias NE. Metabolic acidosis: pathophysiology, diagnosis and management. Nat Rev Nephrol. 2010;6(5):274–285.
10. Kraut JA, Madias NE. Treatment of acute metabolic acidosis: a pathophysiologic approach. Nat Rev Nephrol. 2012;8(10):589–601.
11. Weng W, Wang H, Zhang Y, Chen X, Li M. Association between anion gap and all-cause mortality of critically ill surgical patients: a retrospective cohort study. BMC Surg. 2023;23:226.
12. Dafal A, Benyahia M, Aljassem M. Admission anion gap metabolic acidosis and its impact on patients in medical intensive care unit. Cureus. 2021;13(2):e13107.
13. Kiran HS, Anil GD, Murthy KAS, Gowdappa HB. Severe metabolic acidosis in critically ill patients and its impact on the outcome: a prospective observational study. Int J Sci Stud. 2015;3(8):168–171.
14. Kimmoun A, Novy E, Auchet T, Ducrocq N, Levy B. Hemodynamic consequences of severe lactic acidosis in shock states: from bench to bedside. Crit Care. 2015;19:175.
15. Tangri N, Tan Z, Kramer H, et al. Metabolic acidosis is associated with increased risk of adverse kidney outcomes and mortality in patients with non-dialysis dependent chronic kidney disease. BMC Nephrol. 2021;22:185.